

time, a system receiver will not be seeing the opposing system's transmit power in the receiving system's IF band .

Antenna Gain Limit

Typical antenna beamwidths in use on vehicular radar systems being developed today are 2 to 3 degrees in azimuth and elevation. This beamwidth is used in both the United States and Europe. Of the many design factors that determine beam shape, two major factors are aperture size versus azimuth resolution and power density limitations.

Figure 5 shows the required antenna gain versus the 3 dB beamwidth for a cassegrain antenna with a good efficiency factor of 0.7. As seen in the figure, a two degree beam would equate to a gain of almost 39 dB. In the azimuth (AZ) dimension, the beamwidth is used to define the AZ resolution. The beamwidth, however, increases with range thus degrading AZ resolution. Azimuthal resolution at a range of 60 m is about 2 m for a 2 degree beam. Further refinement in resolution is possible through special signal processing algorithms and/or greater gain. To extend out to 100 meter or greater ranges, or for target trajectory estimating and/or target discrimination, finer AZ resolution is needed but is currently inhibited by antenna aperture. This is true for the 76.5 and 94 GHz bands but less so for the 153 GHz band (due to the relationship of bandwidth being approximately λ/d). In future systems where better resolution in both range and AZ is required for trajectory estimating and target discrimination, higher antenna gains will be needed. Due to auto body style limitations on aperture (e.g. fuel economy/emission requirements), the 153 GHz band is seen as the most promising.

Power density versus antenna gain for various radiated peak powers at R = three meters is shown in Figure 6. Figure 6 does not account for near field effects, where beam divergence does not begin to occur until the range of:

$$2D^2/\lambda \text{ (about 7 m for some systems)}$$

where: D = antenna diameter and,

λ = wavelength

Prior to the divergence, the power density is approximately the peak power divided by the antenna area . However, Figure 6 can be used to approximate the power density in the general sense. For a single auto radar system Figure 7 shows that the peak radiated power requirement could be relatively high and still meet the ANSI average power requirement of 10 mW/cm², provided that ANSI exposure time requirements are met. Even in a multi system environment, the total radiation at 3 m in front of any one system would be only slightly increased. For example, if an oncoming vehicle had a scanning antenna in the adjacent lane and at one point in time the oncoming radar aimed directly at your transmitter, the minimum possible distance between your system and the oncoming system would be about eight meters, Figure 3. The transmitted power density from the oncoming vehicle would attenuate greater than 10 dB for the distance involved. For an opposing system with a peak radiated power of 25 mW, its contributory power density three meters in front of your system would be about 0.003 mW/cm² for a brief moment in time. The contribution of the second field to the total field is negligible.

Figures 5 and 6 clearly show that antenna gain limits need not be reduced below 45 dB. A limit of 35 dB is insufficient, since values of 36 to 38.5 dB are used today as common design practice. To set a limit of 40 dB would place a cap on present systems without allowing or promoting more advanced system development. A gain limit of not less than 45 dB is needed for the 153 GHz band.

Required Peak Radiated Power

The power requirement plots depicting a generic pulsed system with an integration

gain of 1 (Figure 8) and an integration gain of 30 (Figure 9) are provided for reference. From the plots, it is obvious that for extended ranges using Table 3 peak powers that pulse integration is required to achieve a particular probability of detection. Referring to Figure 9, it is obvious that for detection out to 200 to 300 m, 10mW will not be adequate. With only 10 mW peak power, integration gain would need to be much greater than 30. This may exceed system dwell time restrictions thereby making the system impractical.

Currently, the Europeans are proposing 15 dBm (31.6 mW) for both peak and average powers.

Power Requirement Summary

The $30 \mu\text{W}/\text{cm}^2$ at 3 m from the antenna proposed by the FCC Notice equates to about 10 mW peak at the antenna port with an antenna gain of 35 dBi (about 1 mW, antenna gain 45 dBi) using the equation:

$$S = (P G) / (4 \pi R^2).$$

Some of the systems being developed today to meet the necessary range and warning requirements have powers higher than the FCC proposed power density limits. Higher power systems can coexist due to the nature of spread spectrum, as previously discussed. AAMA submits that, for vehicular radar systems to coexist, some form of spread spectrum must be used for optimum performance. The power limit proposed by the FCC would, in fact, inhibit current development and impose design requirements on auto radar systems. Therefore, the proposed AAMA power limits in Table 3 should be adopted. These proposed limits are in keeping with the performance requirement goals necessary to meet the objectives of vehicular radar systems.

Part 2 of Title 47 of the Code of Federal Regulations

The following specific comments and language changes are recommended for Part 2 of Title 47 of the Code of Federal Regulations and referred to as Appendix B in the Notice.

Section 15.253

This paragraph be changed to read: and 152 - 154 GHz.

Paragraph 5(b)

The first sentence be revised read: Operation within 94.7 - 95.7 GHz and 152.0 and 154.0 GHz is restricted a vehicular-mounted field disturbance sensor.

Section 15.253

New Paragraph 5 (1)

AAMA recommends that the FCC not mandate a different power density limit for stationary vehicles (e.g. speed less than 1 km/h). Manufacturers will comply with ANSI C95.1 to meet human safety requirements. Vehicular radar systems such as backup systems need to be in operation before the vehicle is put in motion. If a small object is adjacent to the rear of the vehicle, the operator should be warned of such obstructions prior to putting the vehicle into motion. Also the radar cruise controls and/or collision warning systems may incorporate automatic braking down to zero (0) velocity to minimize the probability of impact and/or the force of impact. To assure both human safety and device functionality, reference to vehicle speed should be removed from this section. A requirement that these devices comply with ANSI C95.1 at all speeds including speeds of zero (0) to one (1) km/h will be sufficient to ensure adequate human exposure limits.

3.0 CONCLUSION

To provide for vehicle radar system benefits such as improved safety resulting in reduced traffic congestion and ancillary benefits, timely specifications are required on IVHS vehicle radar electromagnetic spectrum, operational limits, and test protocol. AAMA submits that the issues addressed in these comments must be resolved for continued development and improvement of vehicular radar.

AAMA and its members are available to discuss any or all of these comments at the convenience of the FCC staff.

Respectfully submitted,

AMERICAN AUTOMOBILE
MANUFACTURERS ASSOCIATION

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Attachments: Figures 1-9

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EXAMPLE OF FM AND
FREQUENCY STEPPED
WAVE FORMS

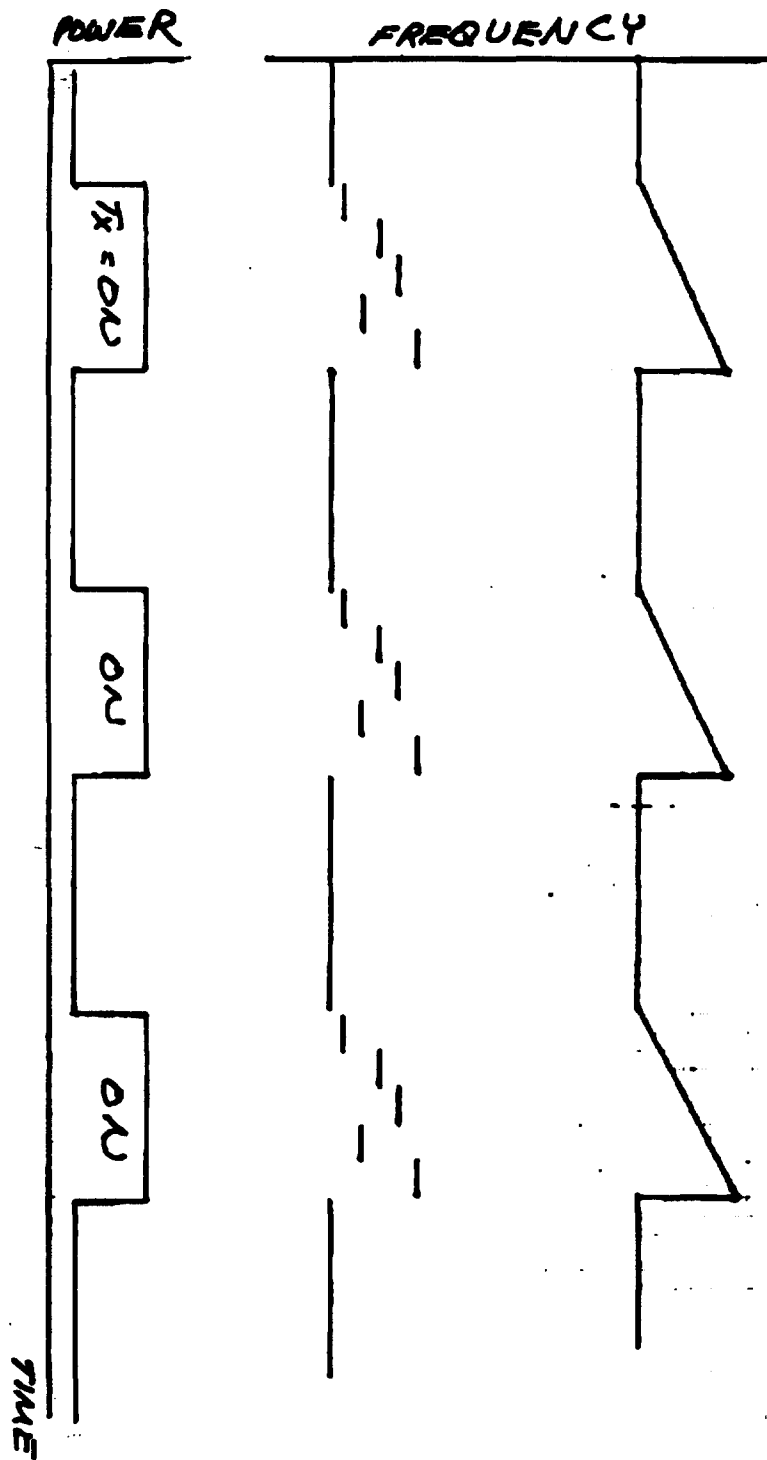


Figure 1.

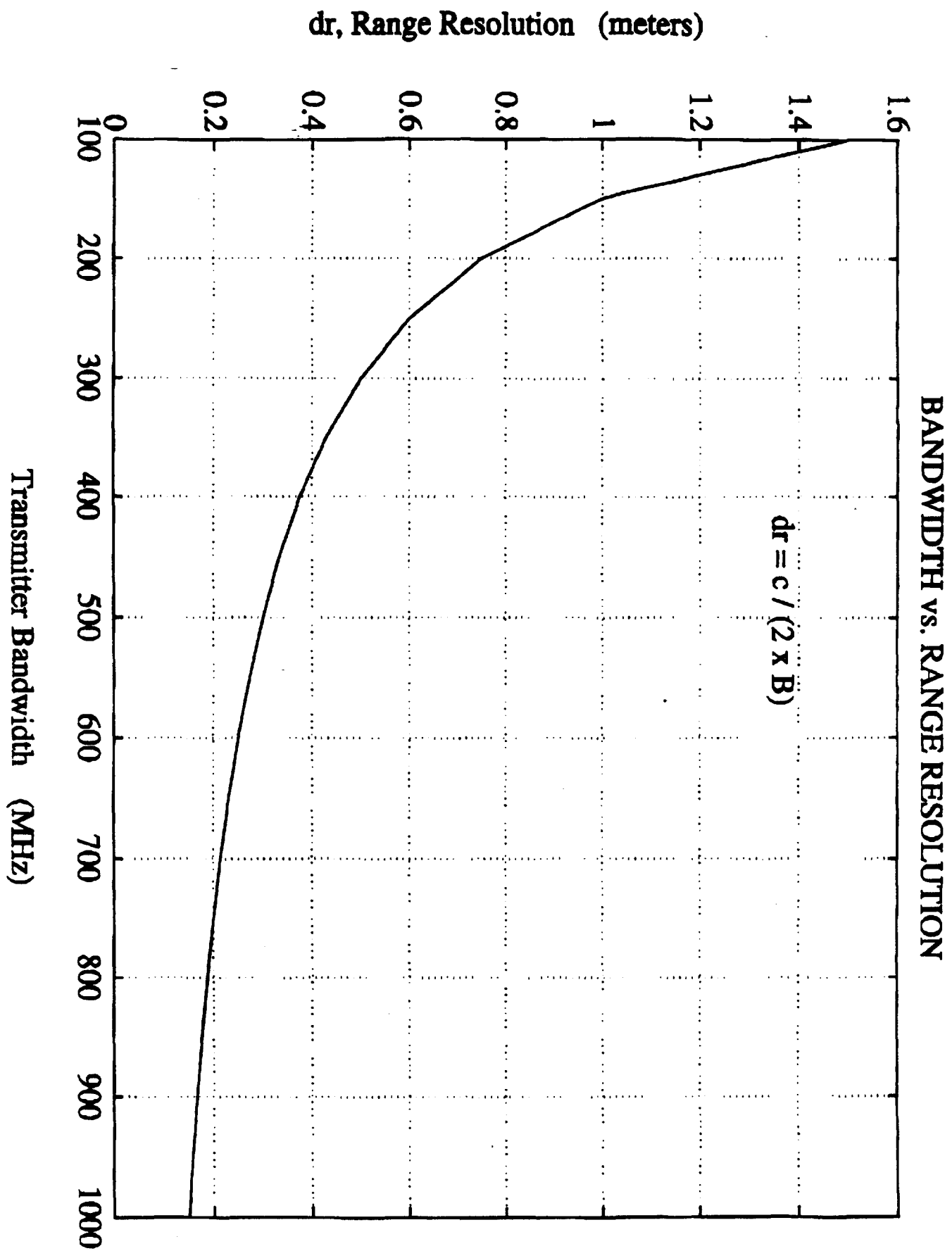
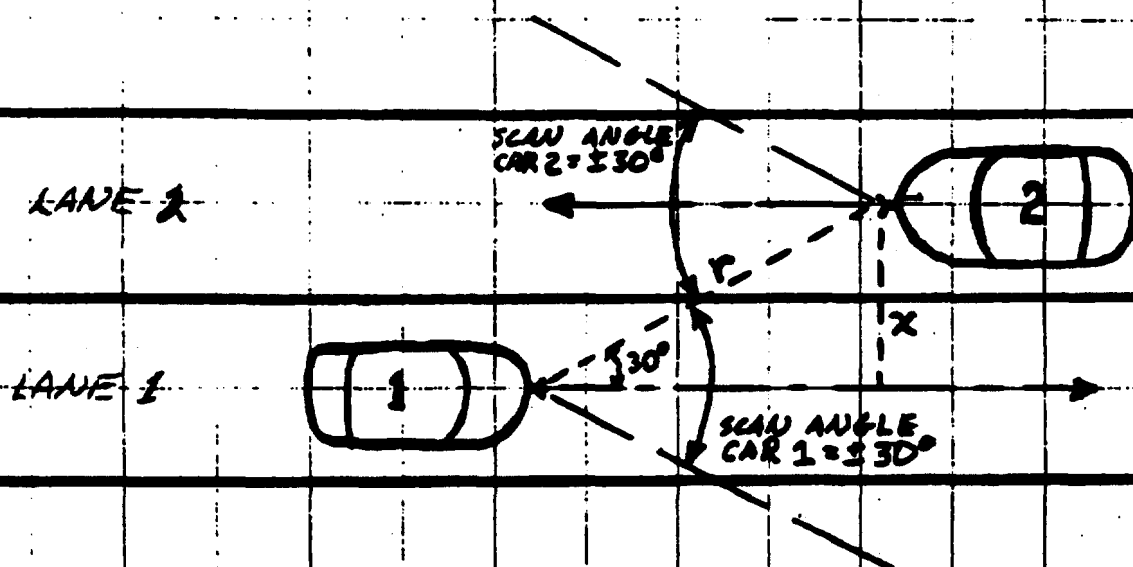


Figure 2.

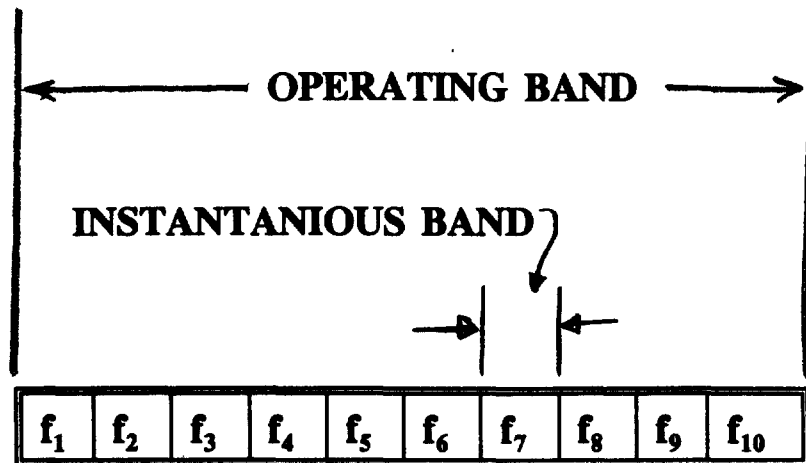
MINIMUM RANGE BETWEEN TWO OPPOSING SLANNING RADAR VEHICLES



$$r = \frac{x}{\sin(30)} = 7.2 \text{ m}$$

WHERE $x = 3.6 \text{ m}$

Figure 3. MINIMUM SLANT RANGE - VEHICLE TO VEHICLE



REFERENCE SYSTEM



OPPOSING SYSTEM

TIME →

OPERATING BAND = RECEIVER RF

INSTANTANIOUS BAND = RECEIVER IF

Figure 4

AAMA: TABLE 2.1 note (2), antenna gain limit

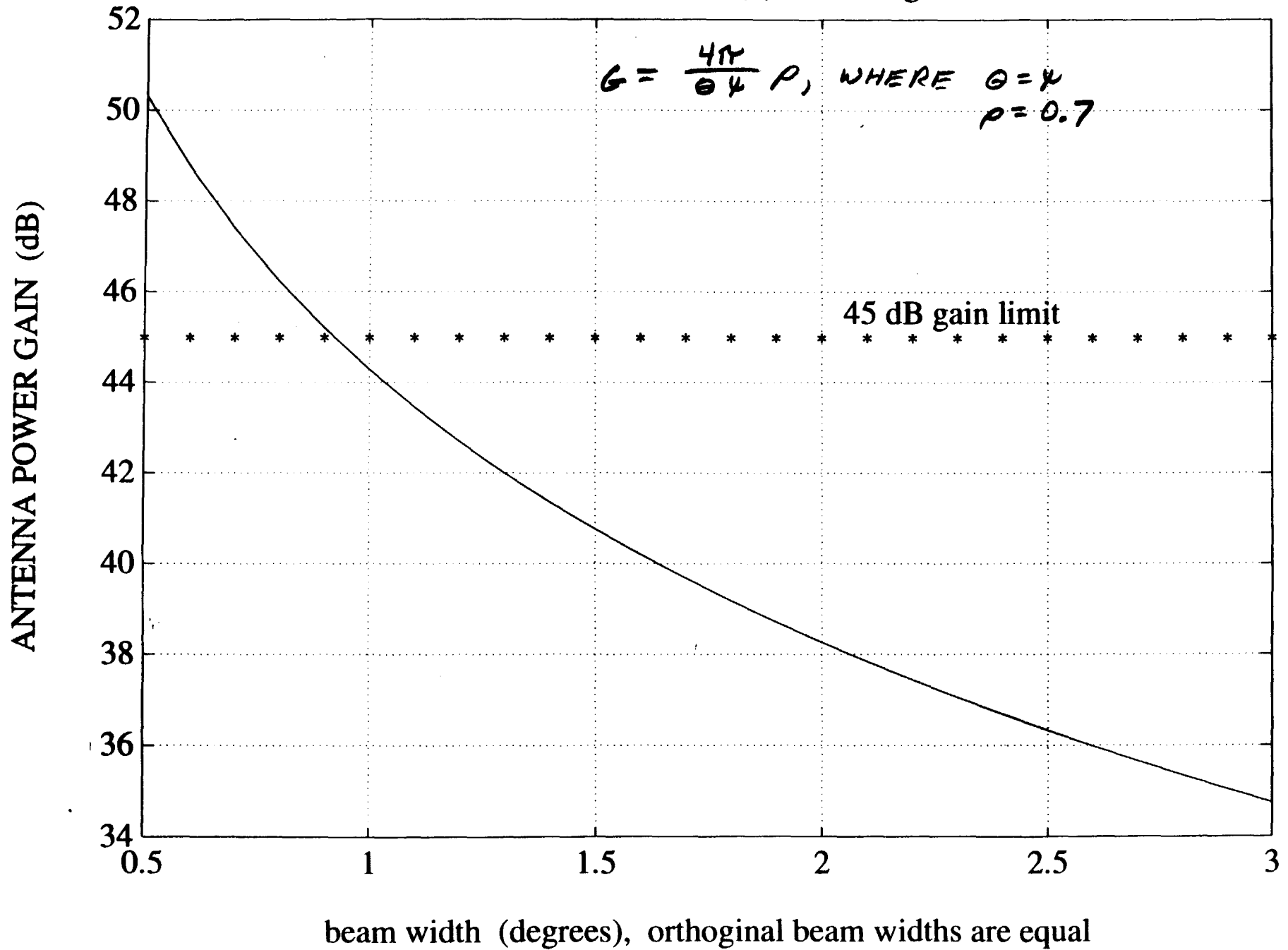


Figure 5.

POWER DENSITY vs. ANTENNA GAIN @ R = 3m

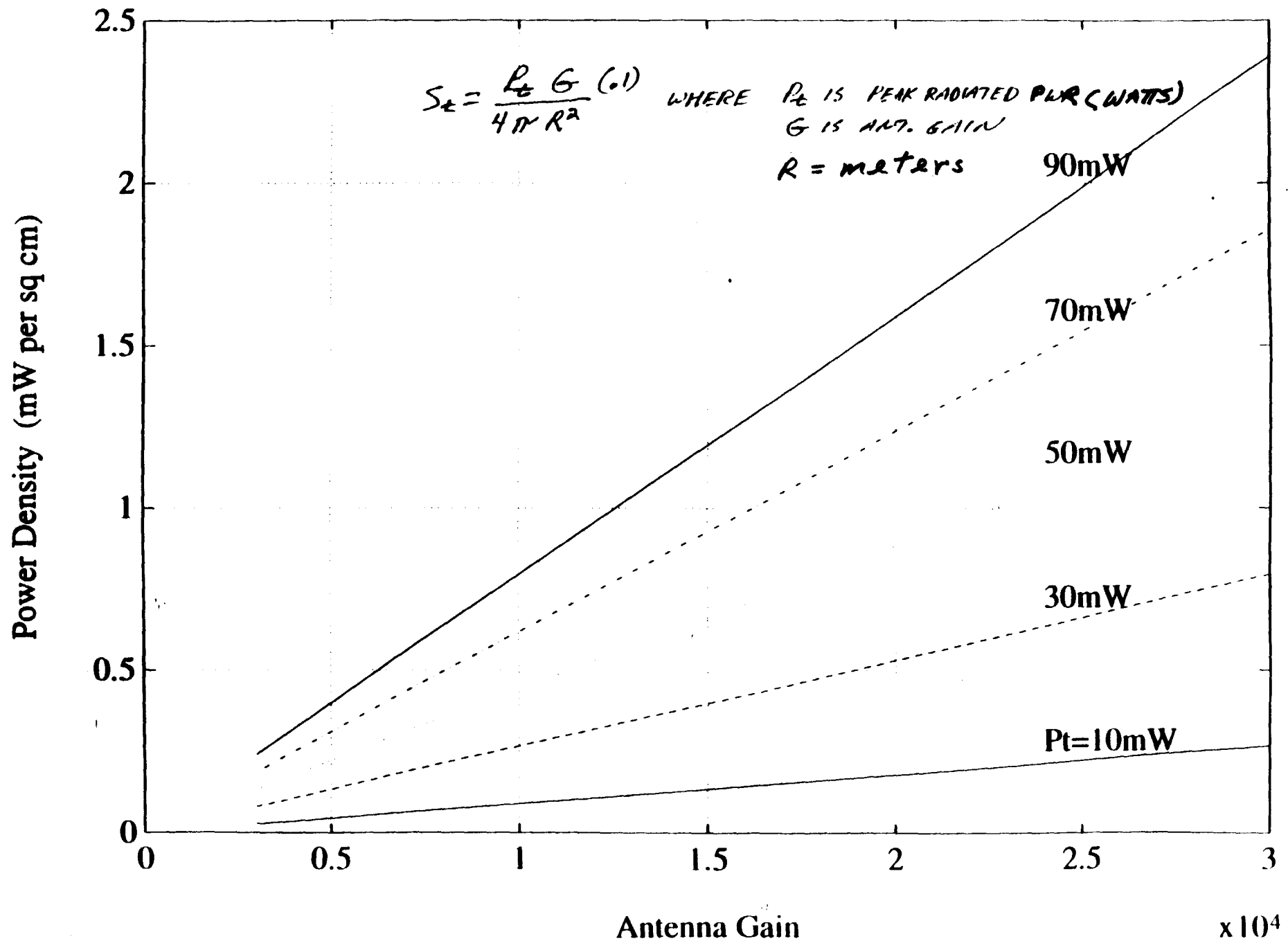


Figure 6.

REQD TRANSMIT PEAK POWER w/ integration gain = 30

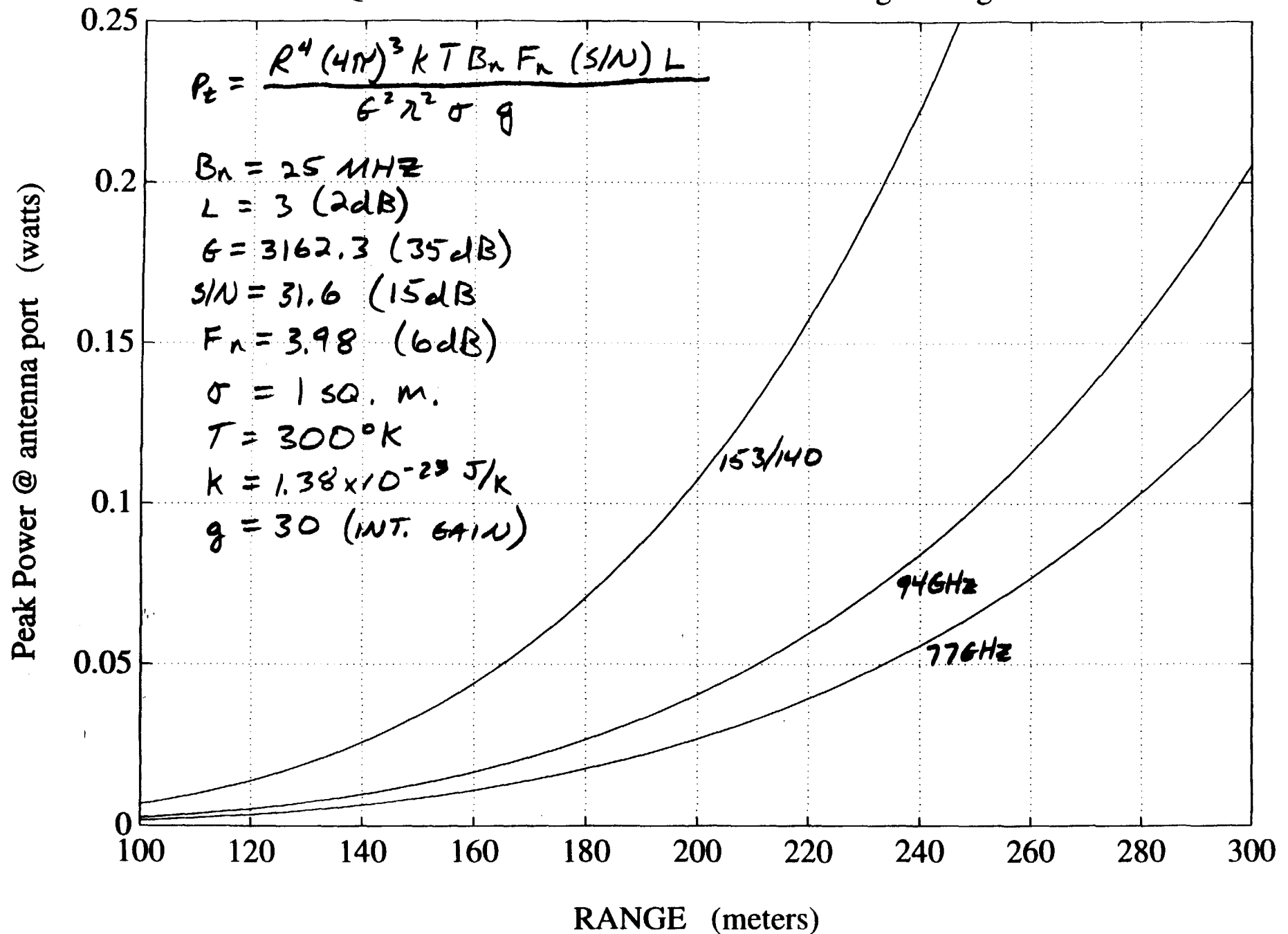


Figure 7.

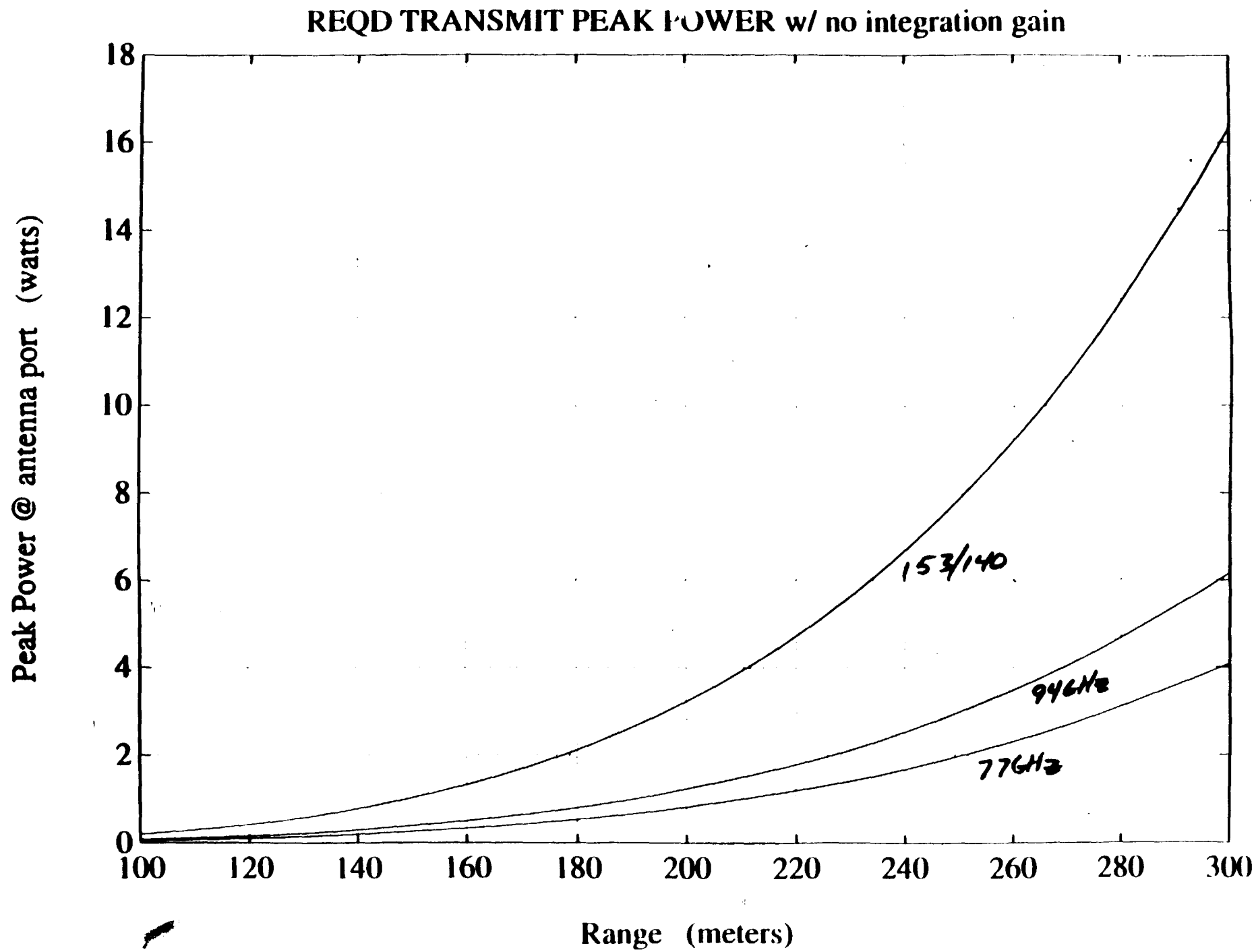


Figure 8.

REQD TRANSMIT PEAK POWER w/ integration gain = 30

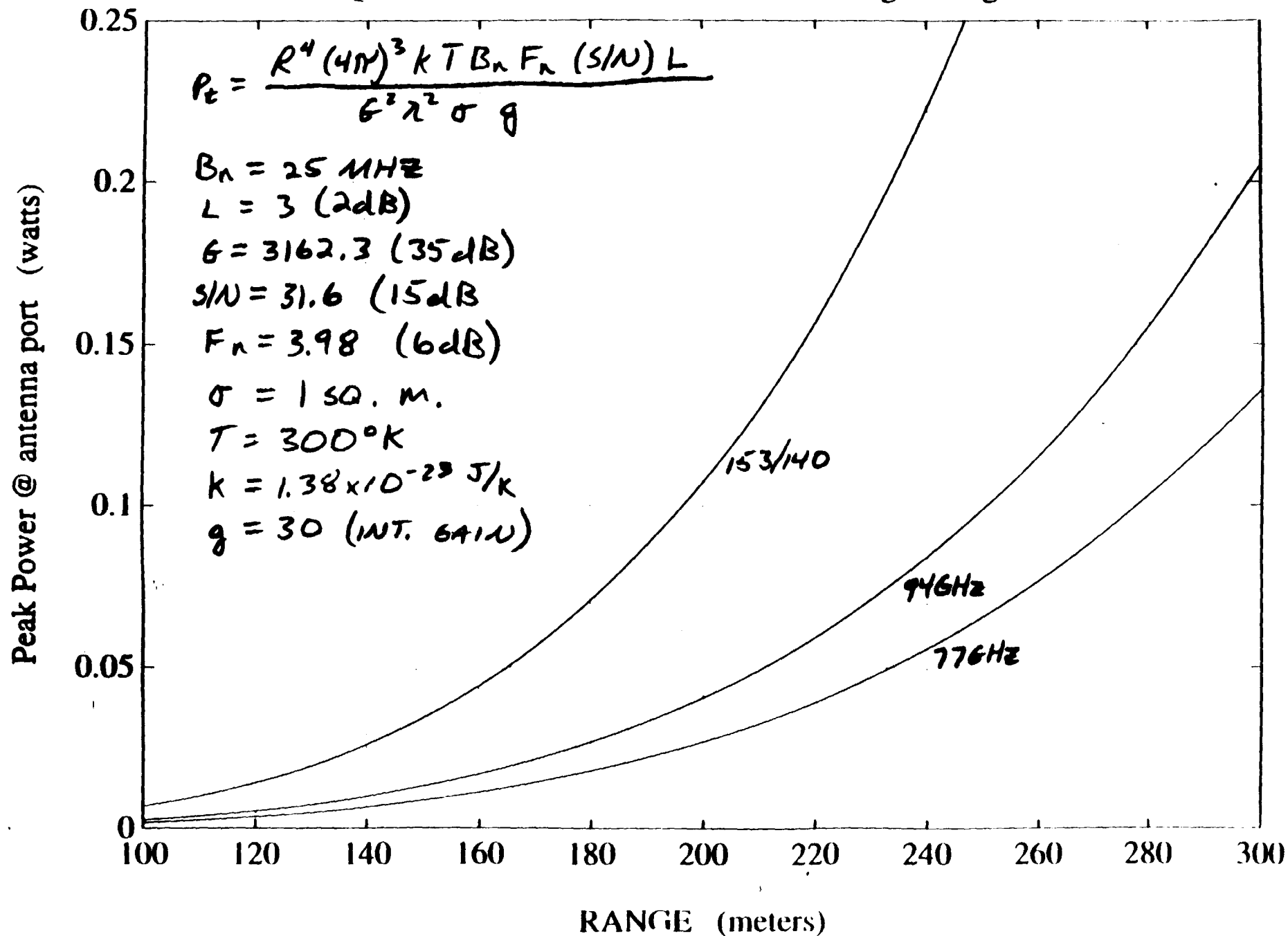


Figure 9.